Probabilistic Evaluation of Storm Surge in Suruga Bay Employing Stochastic Typhoon Model

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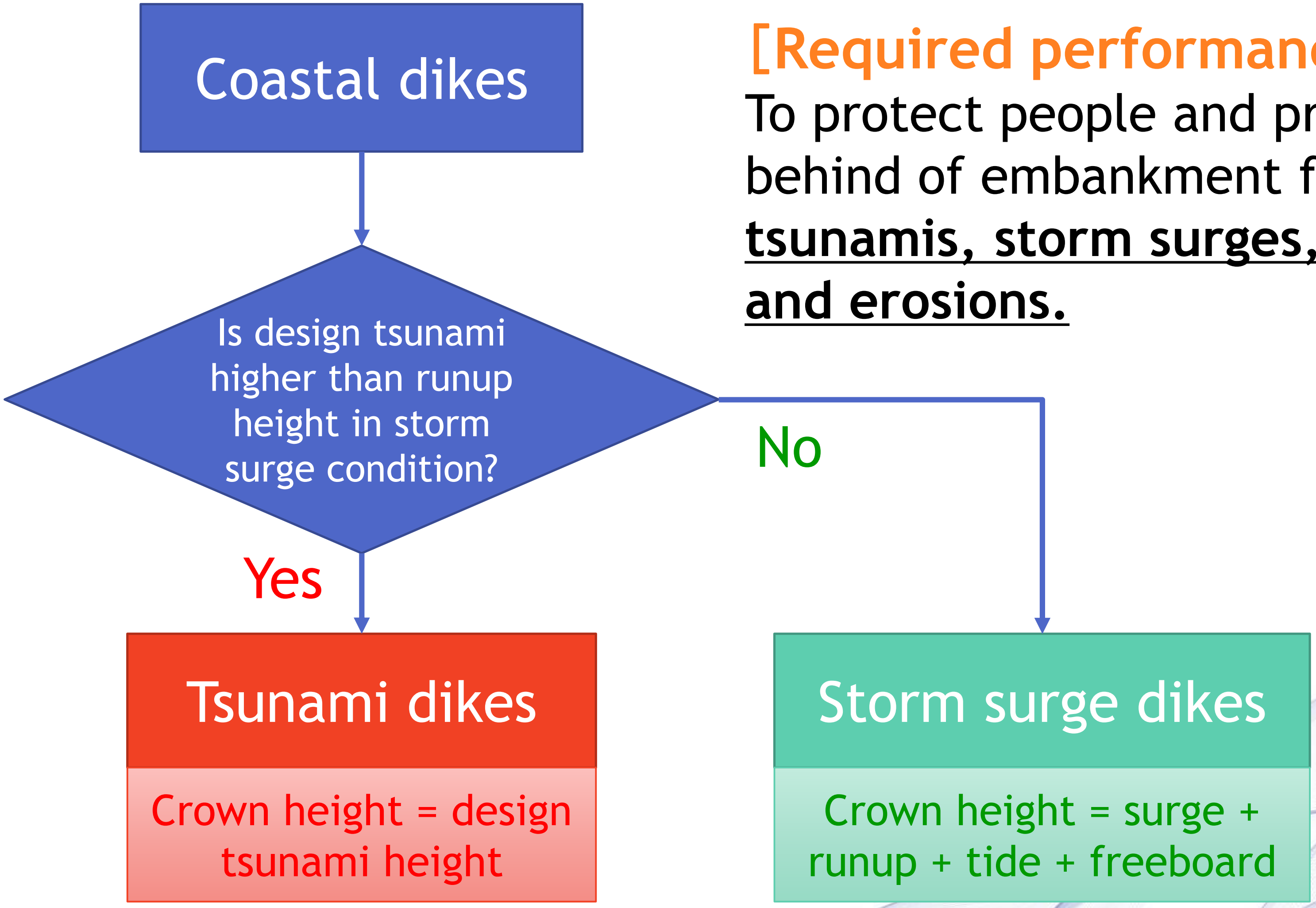
Design procedure of crown height of coastal dikes in Japan

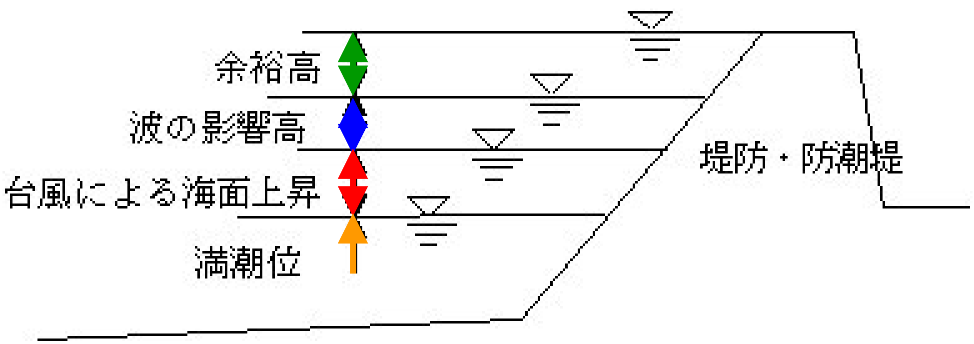


[Required performance]

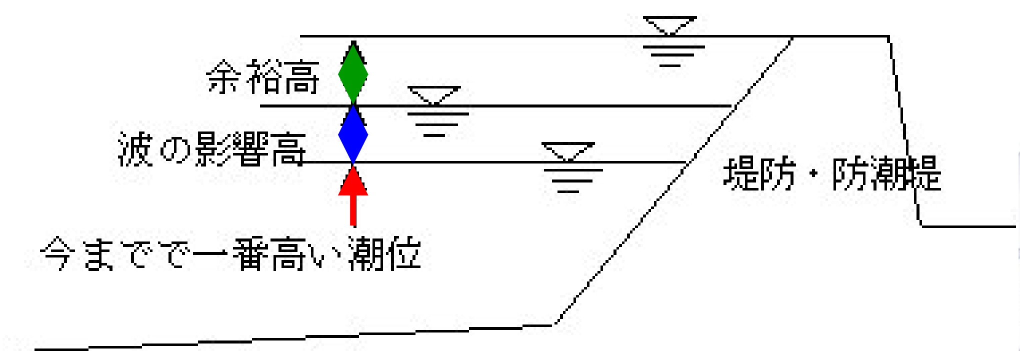
To protect people and property behind of embankment from **tsunamis, storm surges, waves, and erosions.**

Design concept of crown height of storm surge dikes in Japan

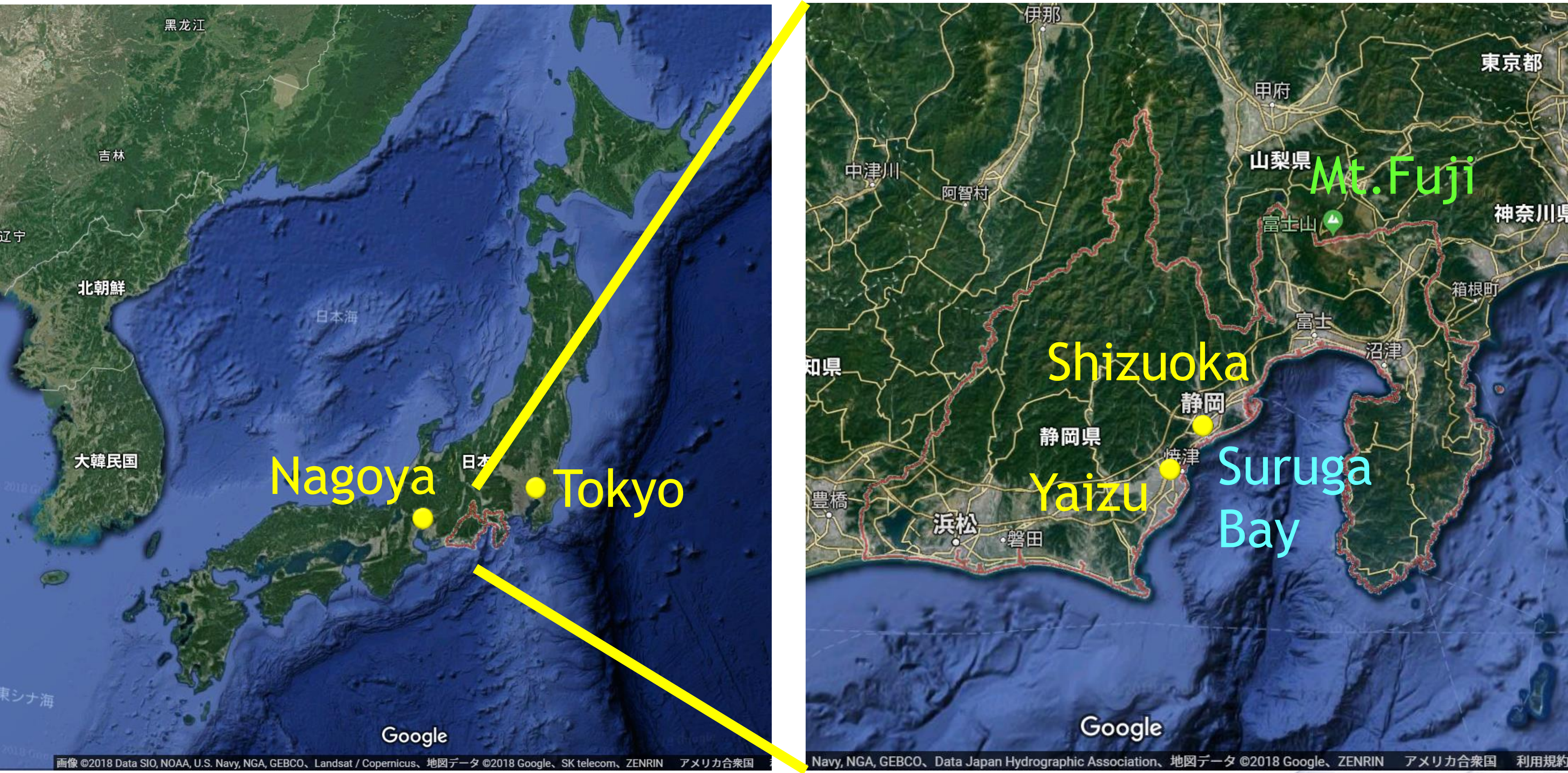
1. Mean spring tide (HWL) + Storm surge by typhoon (Isewan Typhoon (VERA))+ Wave runup + Freeboard



2. Historical highest tide level + Wave runup + Freeboard

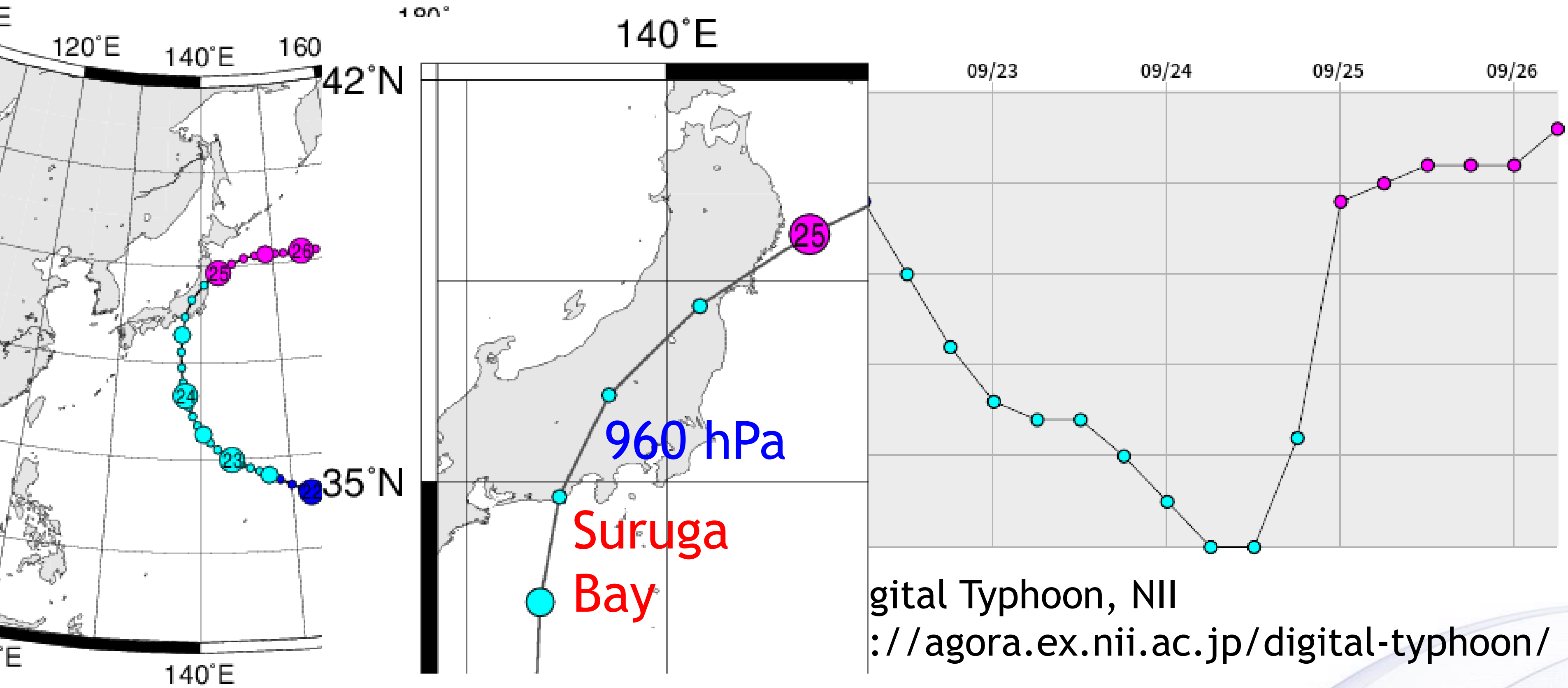


Target area — Suruga Bay, Shizuoka



Suruga coast had been repeatedly damaged by storm surge in 1960’s to 80’s (Sep 1966, Jul 1968, Jul 1972, and Oct 1980).

Historical record of most hazardous typhoon in Suruga Bay (TY No.26 in Sep 1966)

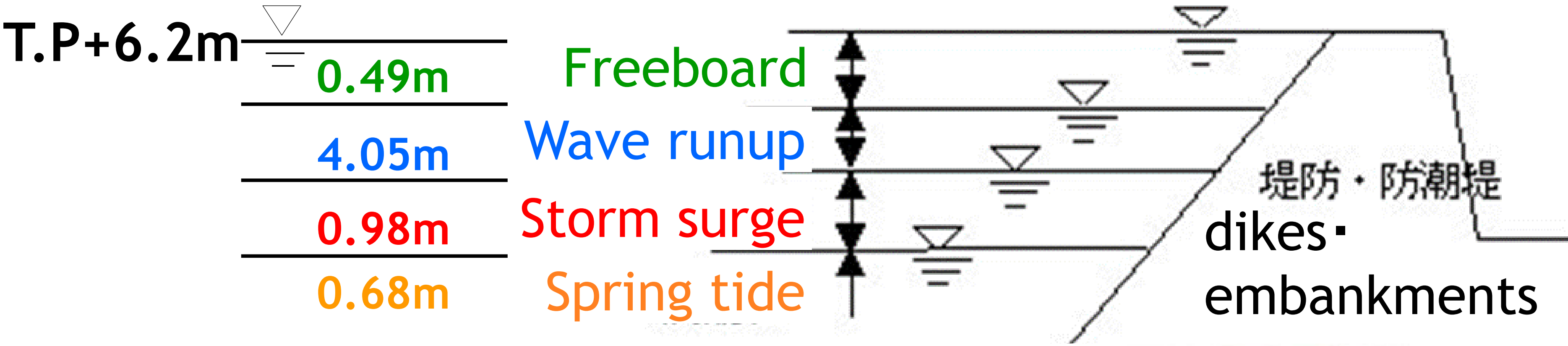


gital Typhoon, NII
://agora.ex.nii.ac.jp/digital-typhoon/

Dike breach 770 m (in Yaizu), 4 death and 8 injured, 10 collapsed and 15 partially damaged houses

Design concept of dikes at Suruga Coast

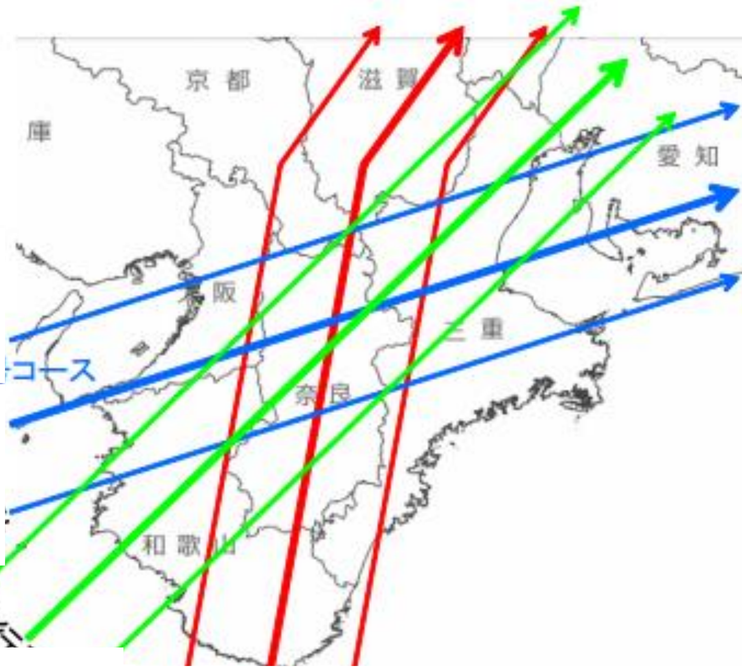
<Design height of existing dikes>



2013~<Construction improvement plan>

Considering effect of typhoon tracks

- New manual issued by MLIT for inundation area estimation by storm surge suggests to check the effect of typhoon track differences.



1971
TY No.29

Track shift
in parallel

1979
TY No.20

1959
TY No.15 (Isewan Typhoon)

Deterministic approach

To project the worst case, Muroto Typhoon model (910 hPa) is recommended to use instead of Isewan Typhoon model (940 hPa).

Purpose of this study

Synthetic fault slip model

Probabilistic tsunami hazard assessment

T_{50}, T_{100}, T_{150}
(Tsunami return period)

Stochastic typhoon model

Probabilistic storm surge hazard assessment

S_{50}, S_{100}, S_{150}
(Strom surge return period)

Setting crown height Ho of dikes

SLR

- This study proposes **probabilistic** evaluation procedure of storm surges employing stochastic typhoon model.
- S_{50}, S_{100}, S_{150} in every regional coasts will be estimated.

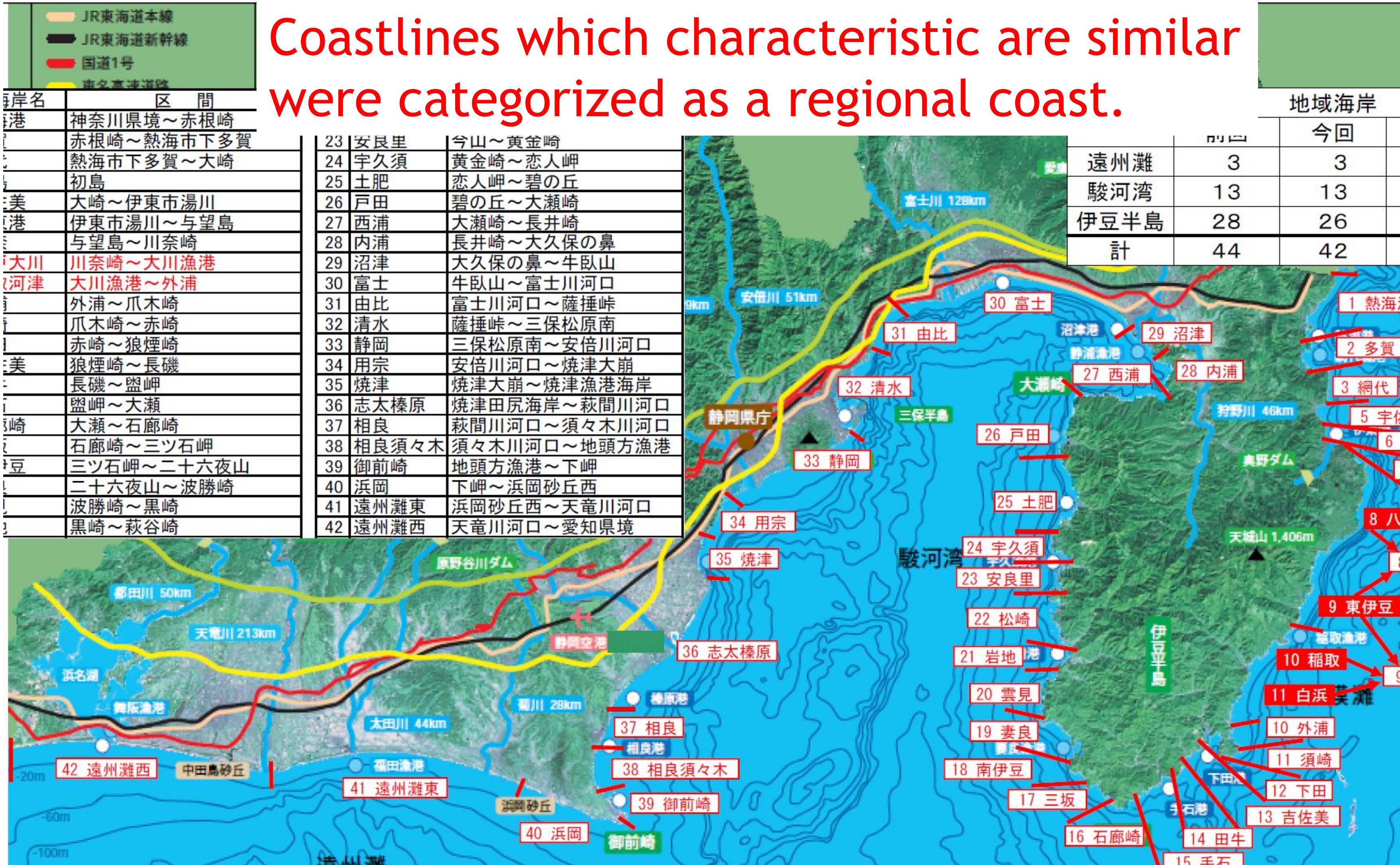
Regional coasts in Shizuoka

Coastlines which characteristic are similar were categorized as a regional coast.

岸名	区　間
港	神奈川県境～赤根崎
	赤根崎～熱海市下多賀
	熱海市下多賀～大崎
	初島
美	大崎～伊東市湯川
港	伊東市湯川～与望島
	与望島～川奈崎
大川	川奈崎～大川漁港
河津	大川漁港～外浦
	外浦～爪木崎
	爪木崎～赤崎
	赤崎～狼煙崎
美	狼煙崎～長磯
	長磯～盥岬
	盥岬～大瀬
崎	大瀬～石廊崎
	石廊崎～三ツ石岬
豆	三ツ石岬～二十六夜山
	二十六夜山～波勝崎
	波勝崎～黒崎
	黒崎～萩谷崎

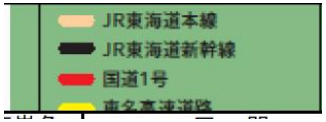
23	安良里	今山～黄金崎
24	宇久須	黄金崎～恋人岬
25	土肥	恋人岬～碧の丘
26	戸田	碧の丘～大瀬崎
27	西浦	大瀬崎～長井崎
28	内浦	長井崎～大久保の鼻
29	沼津	大久保の鼻～牛臥山
30	富士	牛臥山～富士川河口
31	由比	富士川河口～薩捶峠
32	清水	薩捶峠～三保松原南
33	静岡	三保松原南～安倍川河口
34	用宗	安倍川河口～焼津大崩
35	焼津	焼津大崩～焼津漁港海岸
36	志太榛原	焼津田尻海岸～萩間川河口
37	相良	萩間川河口～須々木川河口
38	相良須々木	須々木川河口～地頭方漁港
39	御前崎	地頭方漁港～下岬
40	浜岡	下岬～浜岡砂丘西
41	遠州灘東	浜岡砂丘西～天竜川河口
42	遠州灘西	天竜川河口～愛知県境

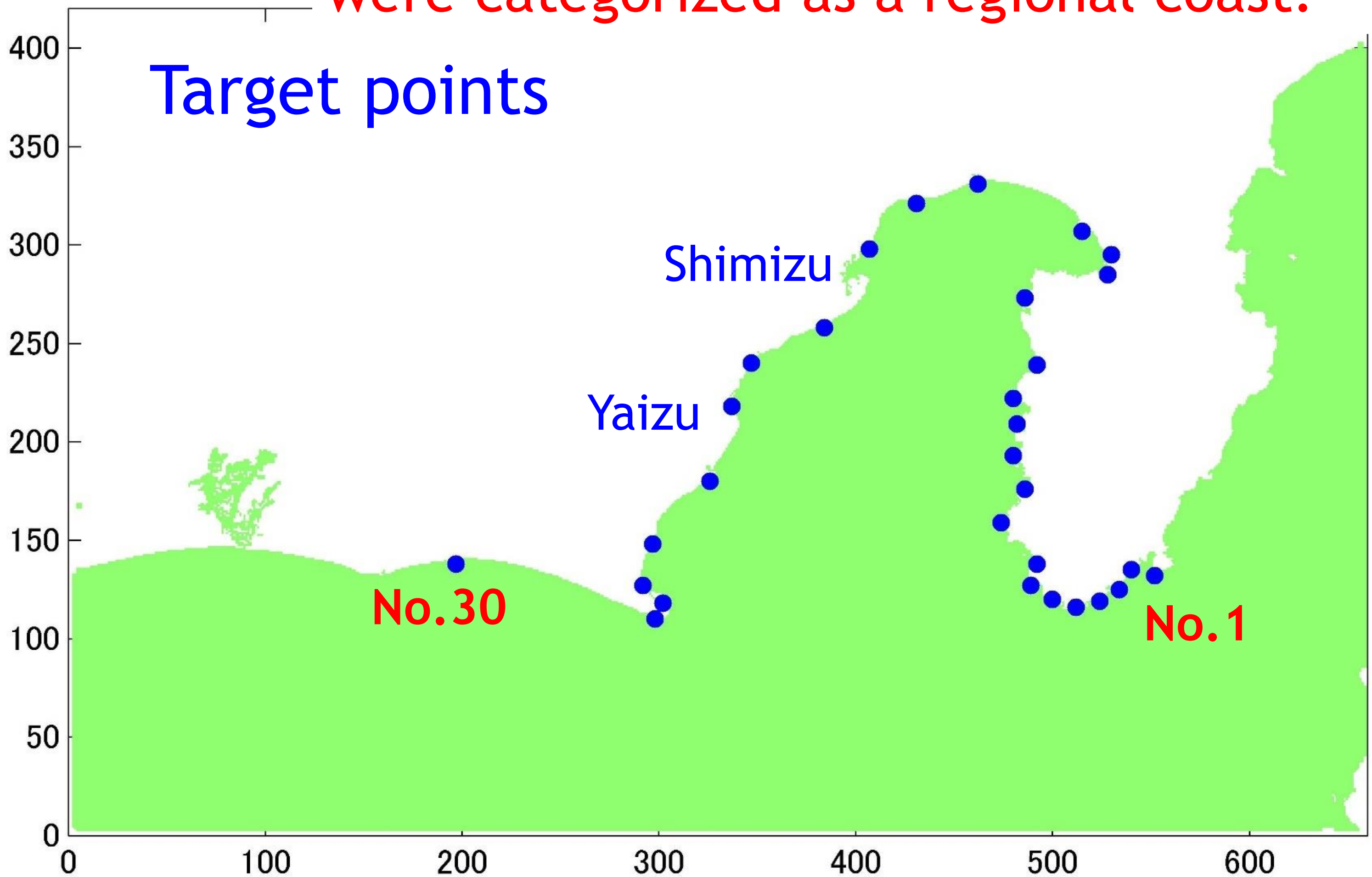
地域海岸	前回	今回	差
遠州灘	3	3	±0
駿河湾	13	13	±0
伊豆半島	28	26	−2
計	44	42	−2



Regional coasts in Shizuoka

Coastlines which characteristic are similar were categorized as a regional coast.





地域海岸		
前回	今回	差
3	3	±0
13	13	±0
28	26	−2
44	42	−2

Research Procedure

- STM (Stochastic tropical cyclone model): Nakajo et al.(2014)

- JMA's empirical formula

$$h = a(1010 - P_m) + bU_{10}^2 \cos(\theta_0 - \theta)$$

- NLSW models
  - SuWAT: Kim et al.(2008)

- Hazard curve
- Recurrence period estimation

Flow of STM (Nakajo et al. 2014)

Genesis number PDF

Genesis location 2D-PDF

Each TC property PDF

Each property change rate

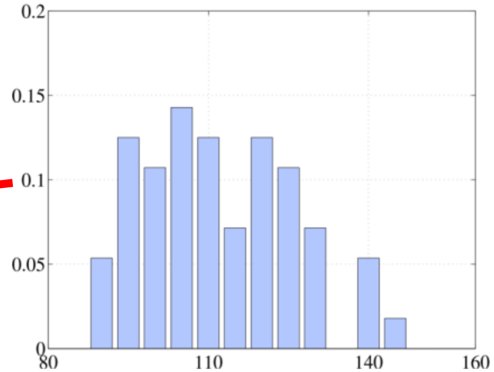
Next time step values

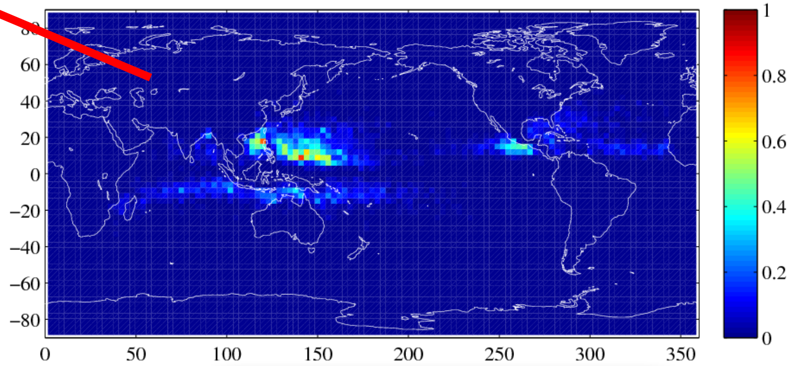
$$f_{i+1} = f_i + df/dt \times dt$$

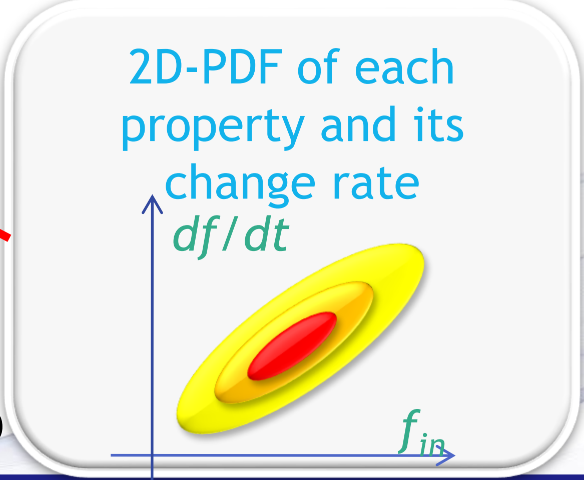
Decision of cyclolysis

Go to next TC

Go to next time step



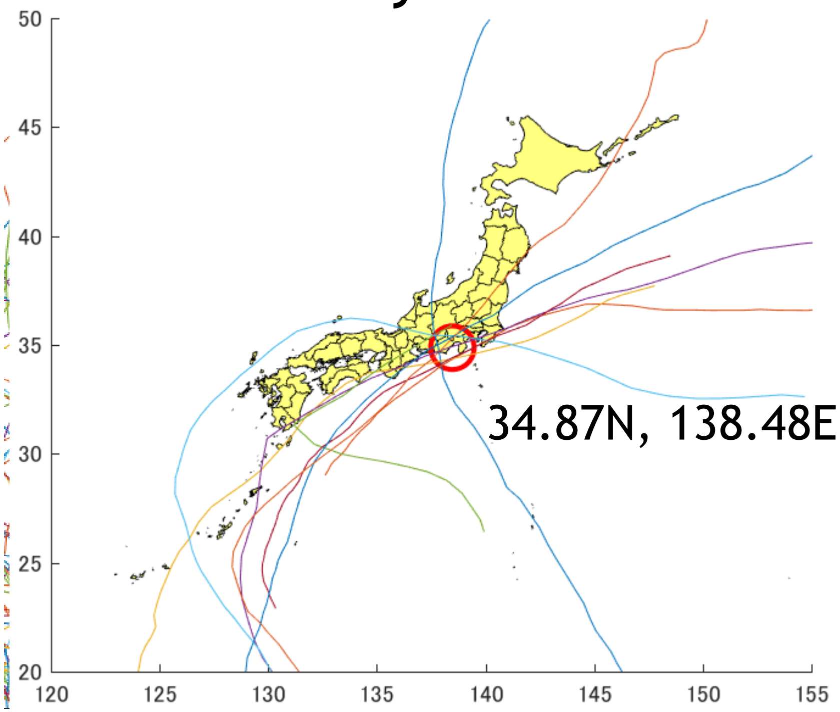




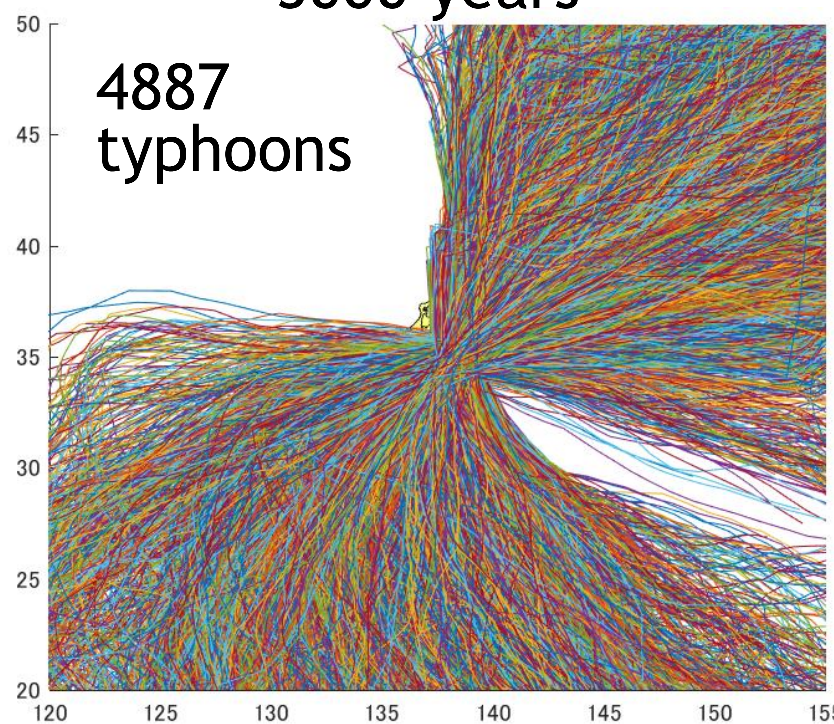
Extraction of synthetic typhoon data

- Typhoon tracks passed the target area are extracted from synthetic typhoon track data set for 5000 years.
- Typhoons which passed within the area of radius of one degree from Suruga Bay are targeted.

10 years

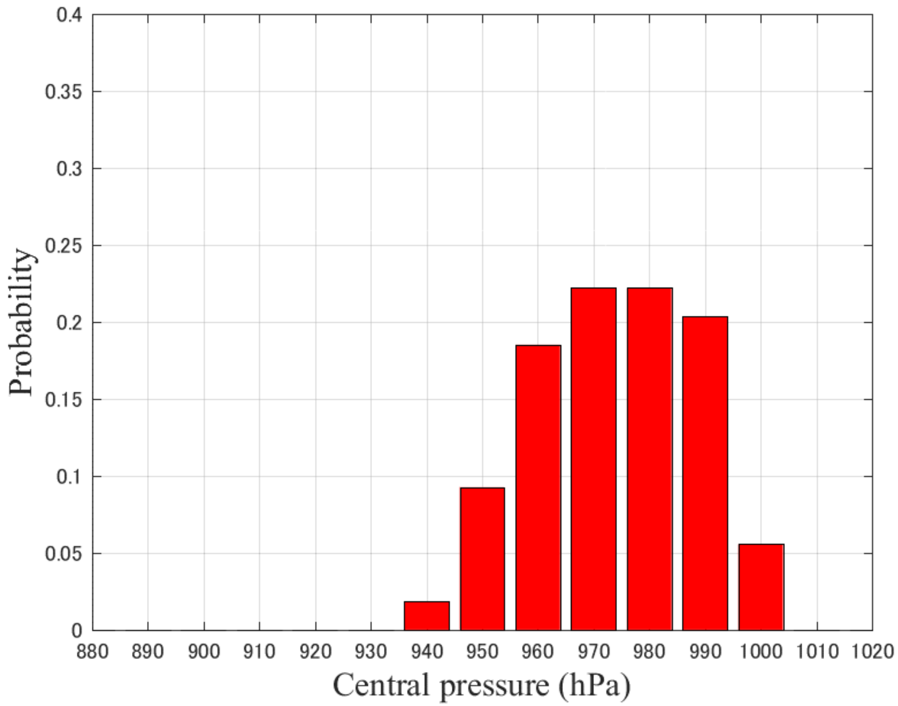


5000 years

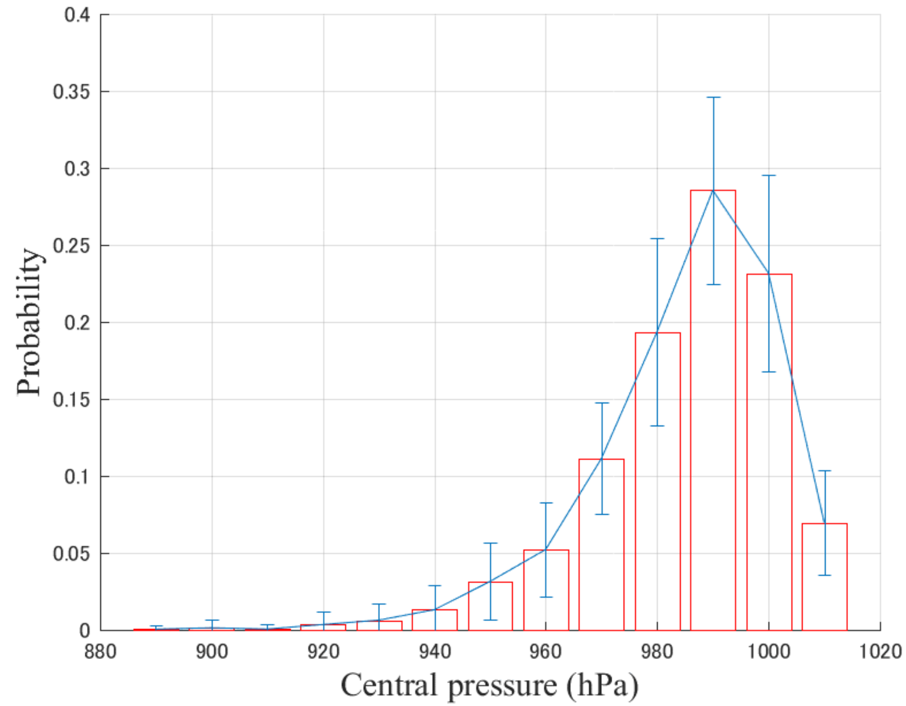


Validation of typhoon characteristics by STM

Observation (1951~2015)

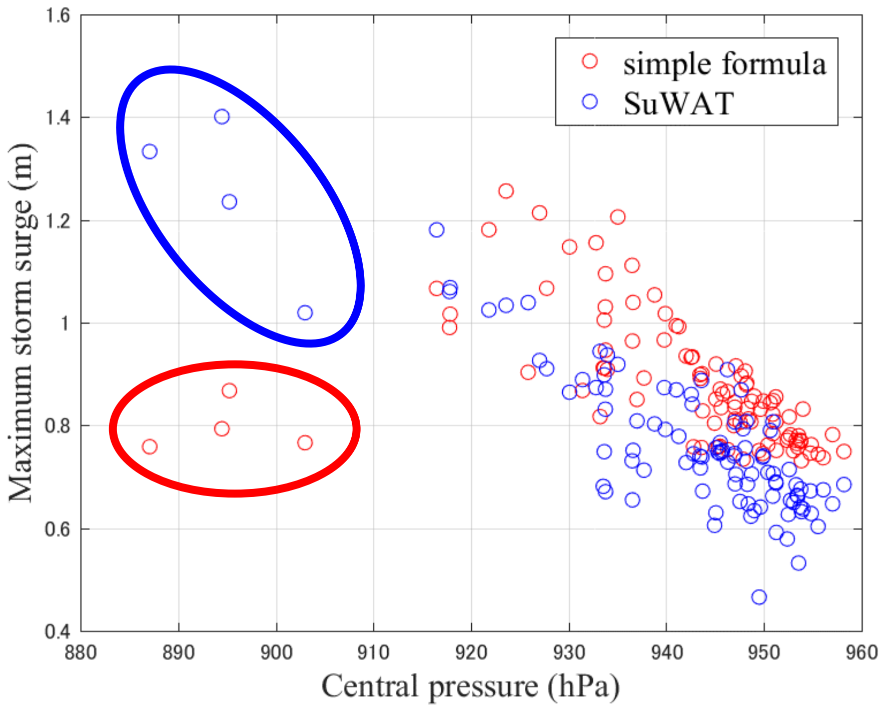


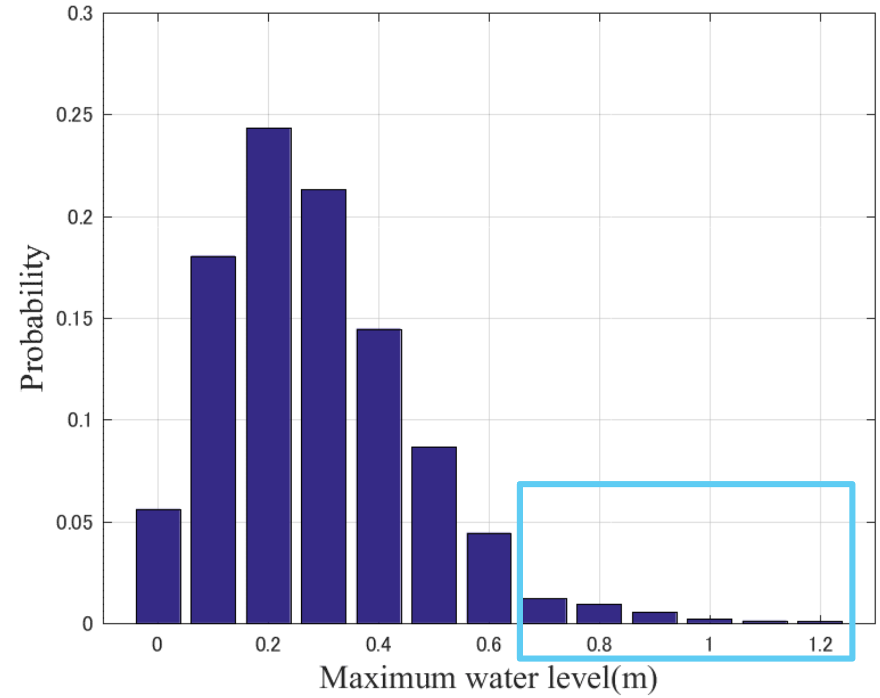
STM (50 years)



- Observed typhoon data from the database by National Institute of Informatics are also analyzed and performance of STM are checked.
- Average numbers of typhoons which pass the target area become 0.8 per year for the observation while 0.9 per year for STM.

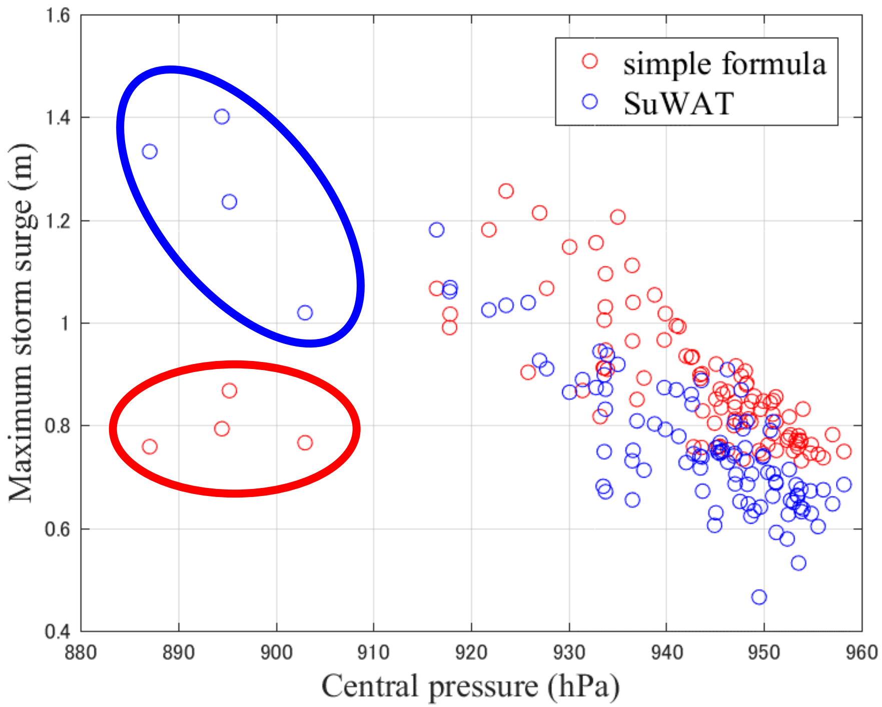
Storm surge calculation by empirical formula

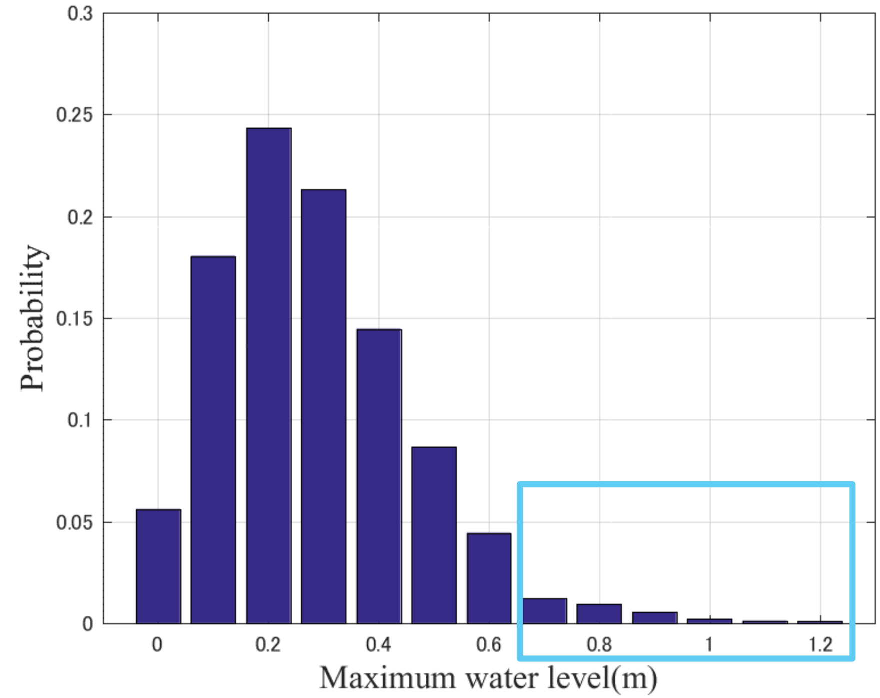




- Storm surges are calculated by an empirical formula which was used by the JMA till 1998. $h = a(1010 - P_m) + bU_{10}^2 \cos(\theta_0 - \theta)$
- Although estimation of storm surge by the empirical formula needs little computational cost, storm surge heights by the empirical formula are tend to be underestimated for strong typhoons.

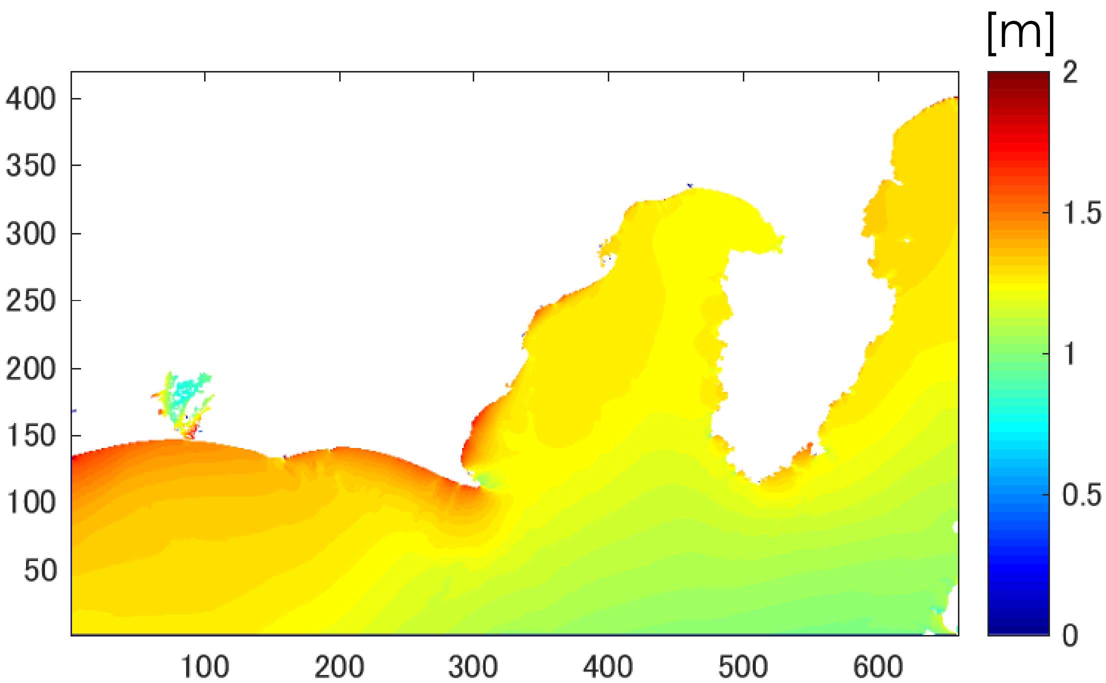
Storm surge calculation by empirical formula

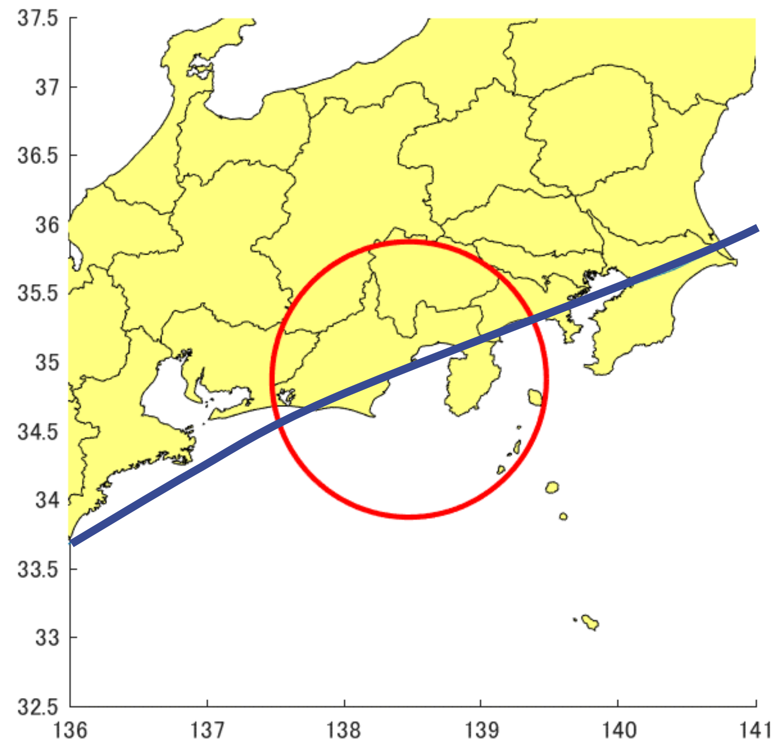




- Storm surge simulations are additionally conducted by the nonlinear shallow water model SuWAT (Kim et al., 2008) for top 100 strong typhoons.

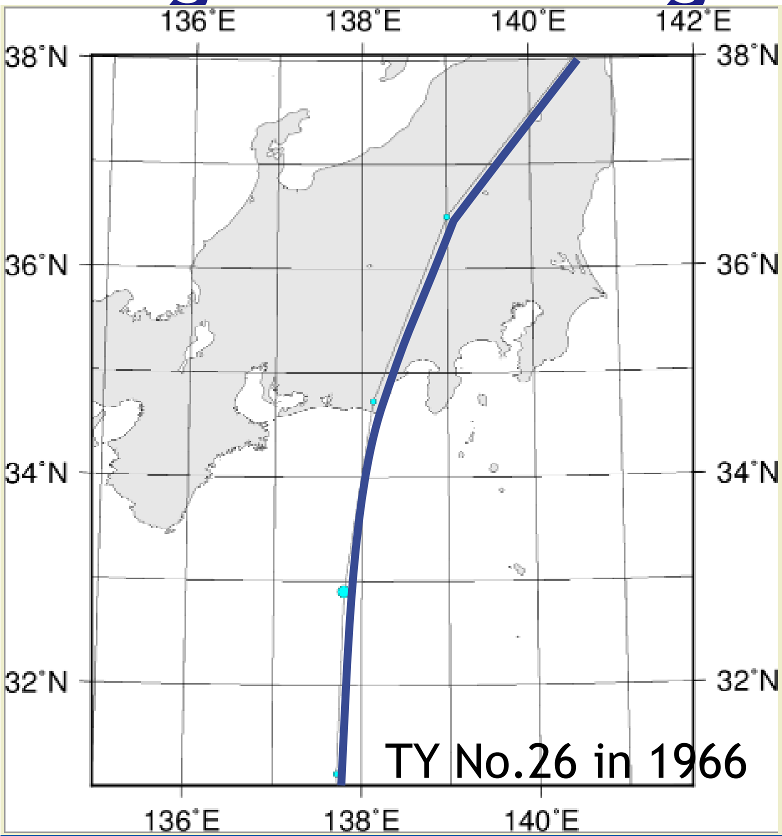
Simulated storm surge generated by the most intense typhoon

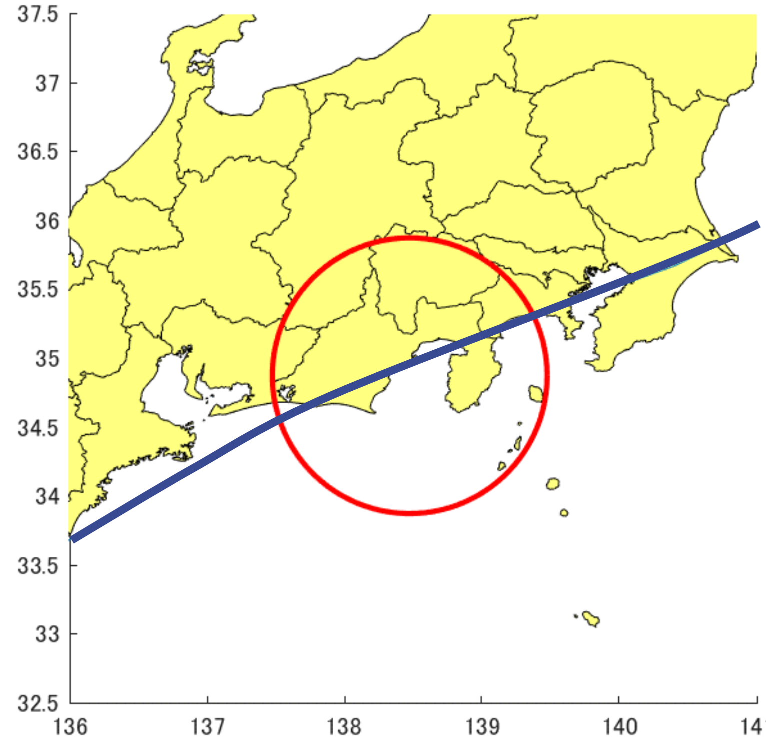




- ☐ Max. storm surge: 1.24 m at Shimizu
- ☐ Min. central pressure in target area: 895.3hpa

Typical typhoon track which generates high storm surge in Suruga Bay





- Track of typhoon which generated highest storm surge is compared with historical recorded typhoon No.26 in 1966.
- They are similar that typhoon travels southwest to north east.

Recurrence probability (return period) of storm surge

- We consider that occurrence of storm surge follows the Poisson distribution and estimate recurrence probability.
- Hazard curves which is annual exceedance probability are estimated for 30 regional areas along the coast of Suruga Bay.

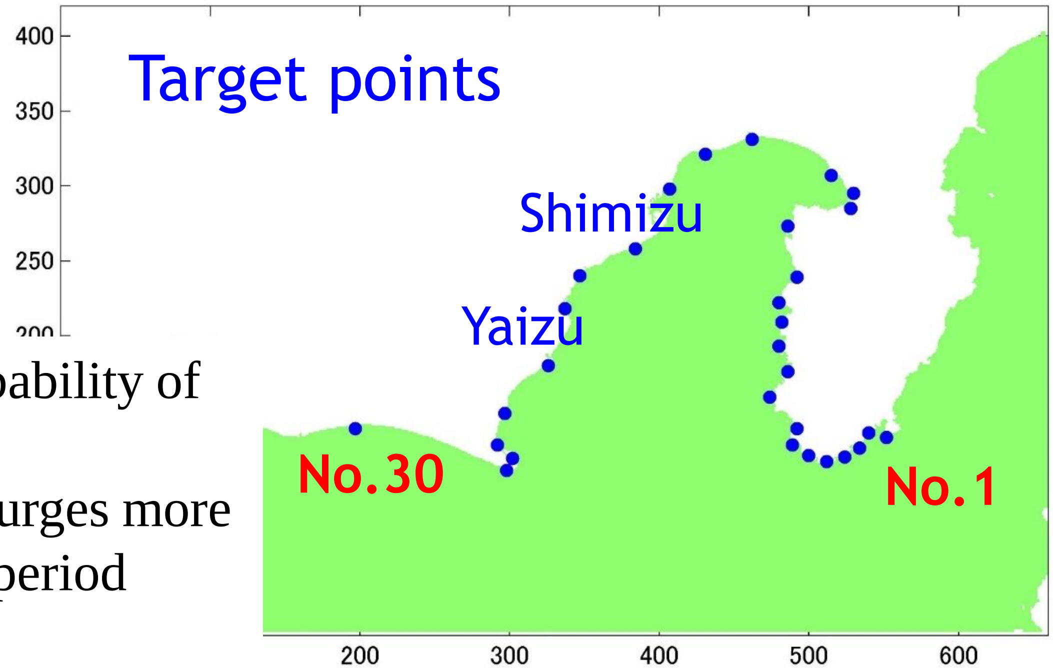
$$P(k) = 1 - \exp\{-v(k)\}$$

$$v(k) = \frac{n_k}{T}$$

$v(k)$: annual mean occurrence probability of storm surge more than k (m)

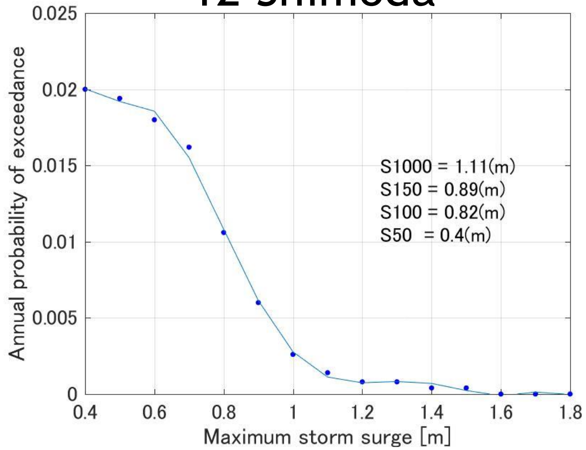
n_k: occurrence numbers of storm surges more than k (m) during observation period

T: observation period (yeas)

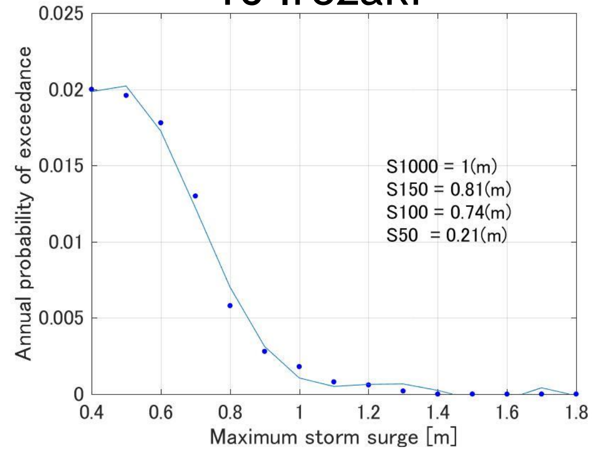


Recurrence probability (return period) of storm surge along Suruga Bay

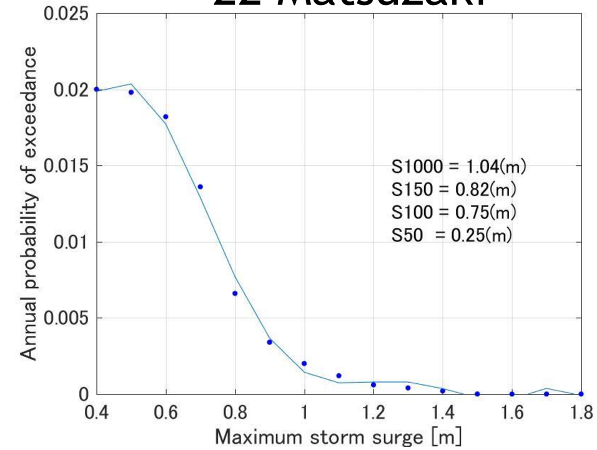
12 Shimoda



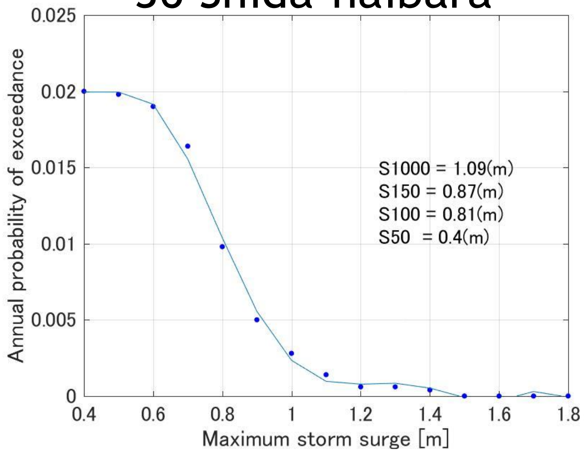
16 Irozaki



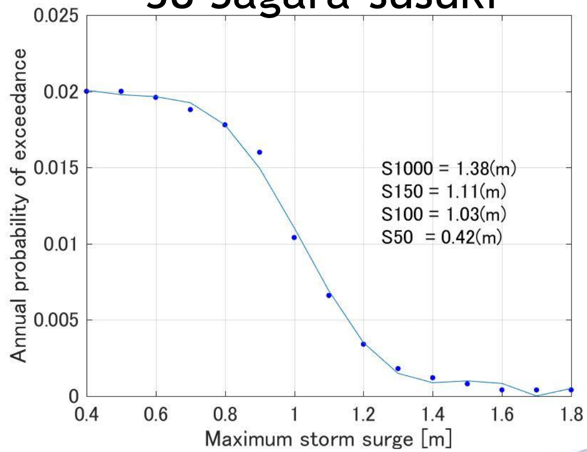
22 Matsuzaki



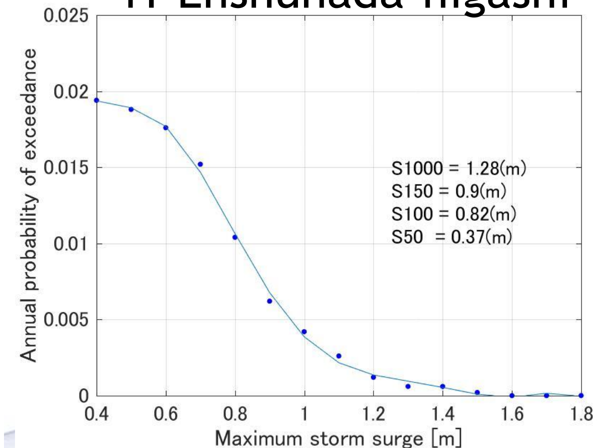
36 Shida-haibara



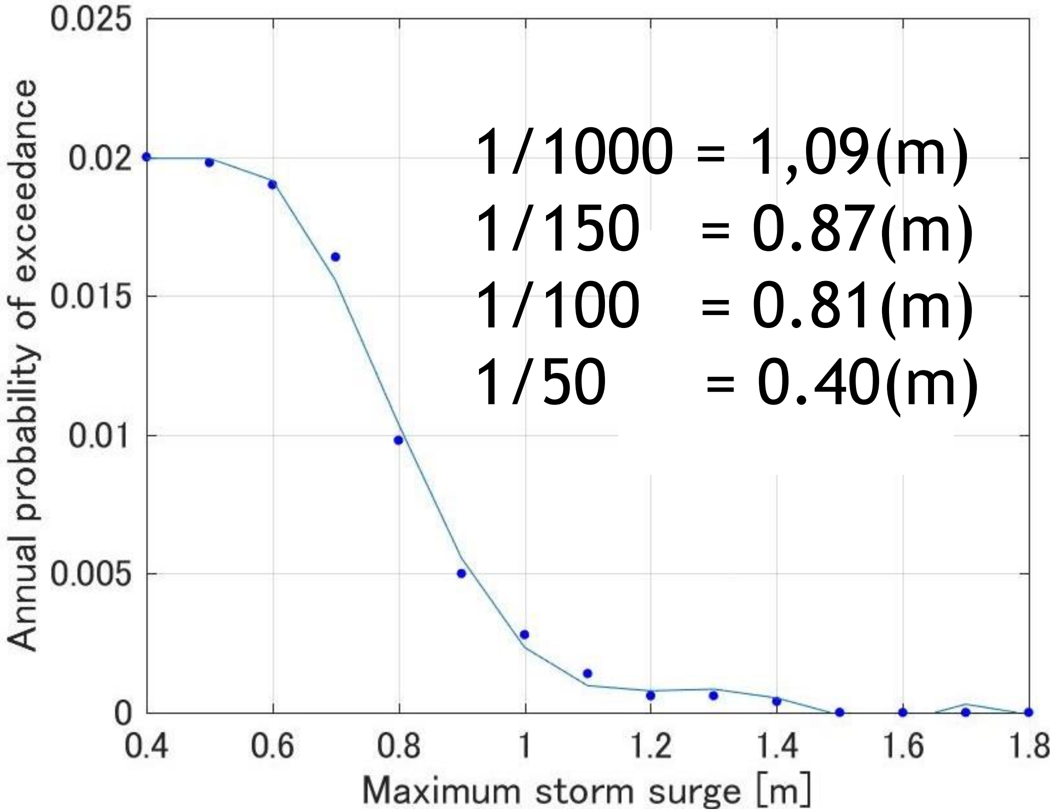
38 Sagara-susuki

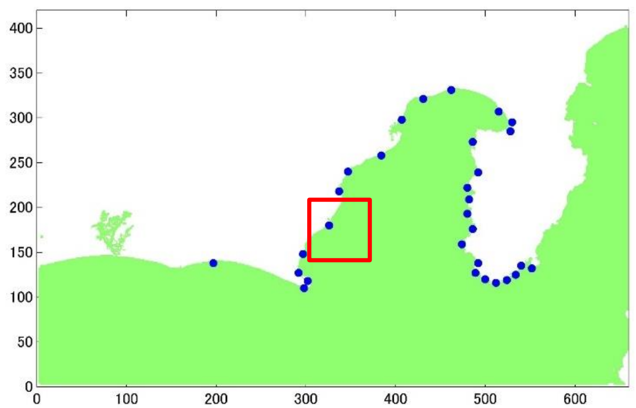


41 Enshunada-higashi



Recurrence probability (return period) of storm surge at Suruga Coast





- The present design storm surge height in Suruga Coast is 0.98 m.
- Statistical analysis estimated a return period of the design storm surge height (0.98 m) is about 270 years.

Conclusions

- This study employed the stochastic typhoon model to estimate the relationship between the magnitude of storm surges and the recurrence probability along the coast of Suruga Bay.
- The estimated hazard curves of storm surge can estimate the return period of the design storm surge in each regional coast.
- Conversely, estimate the storm surge height with respect to the set recurrence probability.
- The proposed method can be applied to other areas.

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Thank you for your kind attentions.

Questions?

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